Introduction

The Big Picture

The type and amount of land cover in an area are important characteristics from the standpoint of understanding the Earth as a system - the cycles of energy, water, and chemical elements essential to life such as carbon, nitrogen, sulfur, and phosphorous. In the energy cycle, land cover influences the reflection of solar radiation from the land surface. This in turn influences the heating of the atmosphere and local and regional climate patterns. The resulting patterns in atmospheric temperature influence the kinds of plants that can live in an area and this largely determines the type of natural land cover. In the water and biogeochemical cycles, variations in the type and amount of land cover influence the cycling of water, carbon, nitrogen, and sulfur among the soil, plants and atmosphere.

Since the mid-1980's, an area of research known as Earth system science has developed to study and understand these processes and the interactions among the atmosphere, *hydrosphere*, *biosphere*, *geosphere*, and *cryosphere*. GLOBE students will be mapping land cover and providing ground observations which will advance their own understanding of the landscape around them as well as the research of Earth system scientists. This mapping involves distinguishing the types, or classes, of cover on the surface.

There are many systems for classifying land use. In GLOBE, we use an adaptation of the international system used by the United Nations which we call the Modified UNESCO Classification (MUC) system. See Tables LAND-P-3 and LAND-P-4.

Identification of the various land cover classes in an area can be done in a number of ways. In studying large areas, satellite data sets are common sources of images of land surface characteristics used to make land cover maps. However, simply examining an image without some specific knowledge of the area involved may reveal little about what the actual land cover is. The best and most accurate source of information on the kinds of land cover comes from visiting the site and conducting a detailed assessment of its characteristics on the ground. The data gathered by your students from such visits constitute an important source of information about the land cover within your 15 km x 15 km GLOBE Study Site. In particular, the detailed data acquired from 90 m x 90 m Land Cover Sample Sites will contribute to a better understanding of the *biomass*, the land cover, and the amount of photosynthesis taking place in your part of the world.

Natural vegetation is so important to the myriad processes and cycles of interest to Earth system scientists that you will be conducting several detailed measurements in some of the ground sites which are dominated by vegetation. These measurements are referred to as *biometry* and they quantify the size and extent of the plants in these sites. This is important information for a variety of reasons:

1. Although humans have extensively modified and replaced natural vegetation, most of the Earth's land surface is still covered by the naturally vegetated ecosystems which evolved in response to local geographical and climatic conditions. The type and nature of the vegetation present therefore tells us a great deal about other environmental variables such as rainfall or temperature.
2. Terrestrial vegetation is a major component of the large system we call Earth. Plants absorb and cycle nutrients - carbon dioxide, nitrogen, sulfur and phosphorus from the atmosphere and soil. They absorb water from the soil, incorporating it into their tissues, and *transpiring* some of it to the atmosphere. Plants also form the basic foundation of the food chains which support other life forms.

3. Vegetation can be a sensitive indicator of change in local or regional environments. Subtle changes in climate or other environmental factors may reveal themselves first as changes in the type or growth of local vegetation.
4. Human-induced changes in vegetation affect not only the plants themselves, but all the important cycles of nutrients and water in which vegetation plays so important a role. To understand the changes taking place in the Earth system, the human-induced and natural changes in land cover must be tracked.
5. Because of the importance of vegetation, the land-oriented satellite sensor (Thematic Mapper) you will use for mapping is designed specifically to identify and discriminate various kinds of vegetation. In addition, recent research has shown that satellite data are sensitive to the amount and health of many types of vegetation, but ground observations are needed to quantify and calibrate these relationships.

For all of these reasons, Earth system scientists are eager to have your maps, and your detailed biometric observations of naturally vegetated ground sites. Your data will tell us how important factors in the Earth system may be changing over time and how sensitive or resilient ecosystems are in the face of environmental change, and will improve our ability to interpret the satellite imagery we rely on to monitor large areas of the Earth's land surface.

Your field observations fill a major gap in scientists' ability to understand our planet because, even with your help, it is virtually impossible to visit the number of sites and collect all the data that we need. There is simply not enough time, money, or energy to get to enough sites. Therefore, the use of remotely sensed data (information collected from photography and satellite imagery) is critical to acquiring all the knowledge we need to understand the Earth as a system. Remotely sensed data can quickly and efficiently cover the entire Earth. As a GLOBE school you are given satellite imagery of a relatively large area compared to your school size. It would be very time-consuming and difficult for you to visit every area in your 15 km x 15 km GLOBE Study Site and yet one Landsat satellite Thematic Mapper image easily covers your area and 100 more like it. Using the tools that are described in this protocol you will generate a land cover map of your entire GLOBE Study Site by manual interpretation and by use of a computer program called MultiSpec. From these land cover maps, using the MUC classification scheme, you and your students will learn much about the area around your school.

Does producing this land cover map take the place of visits to sites on the ground? Absolutely not! The ground data collection is critical to effective use of the remotely sensed information. In order to be able to make the land cover map from the remotely sensed data, it is necessary to have visited some sites on the ground so that you can accurately identify certain sites on the satellite image. Without this ground data it would be impossible to make an effective land cover map from the satellite imagery.

The second use of your ground data is verification of land cover maps. A vital consideration for every scientist is the confidence that she or he can place in data collected by others or by automated systems. Often this confidence is based on some statistical measure, and such is the case in evaluating land cover maps generated from remotely sensed data. In order to have some confidence in a land cover map and make decisions based upon it, it is critical that the map be tested to see how good it is. This validation process is performed by comparing sample areas on the map with actual site visits on the ground. This comparison is then summarized in a table, called a difference or error matrix, which shows how well the land cover map represents what is really on the ground. Without ground data it would not be possible to generate land cover maps from remotely sensed data nor could we validate them once they were created.

GLOBE Student Data as Input to Models

Research scientists will incorporate GLOBE student data into models used in on-going research projects. The long-term goal of their research projects is to understand the primary biogeochemical cycles of Planet Earth. The primary cycles to be studied include those of carbon, sulfur, nitrogen and water. The overall strategy is to use numerical models to study how these cycles function, both in natural systems, where perturbations in the environment are produced primarily by climate variability, and in systems where disturbances have been induced by human activities. Among the GLOBE measurements used as inputs for such models are:

- Land cover class (MUC)
- Maximum/minimum air temperature throughout the growing season
- Precipitation throughout the growing season
- Tree circumference at a height of 1.35 meters and how it changes over time
- Soil moisture throughout the growing season

By collecting data using the *Land Cover/Biology Protocols*, you and your students will become partners in this type of Earth system science research. The essence of a partnership is that each of the participants brings unique strengths which make the collaboration stronger. Your contribution is the intimate knowledge you have, and can obtain, of your local area. The Earth system scientists place that knowledge in the larger context of their models and efforts to understand our whole planet. Only by working together can we hope to know both the details and the integrated picture of the Earth system.

Student Learning Goals

There are two overarching concepts for this investigation. The first is systems, as examined by the sample site and biometry protocols. The sub-concepts involved are productivity, boundaries, inputs, outputs, cycles (seasons, feedback loops). Some of the processes are representative sampling, indirect and direct measurements, classification (using generalizations and choices), and drawing conclusions based upon evidence.

The second overarching concept is models, and is particularly important for the mapping and accuracy assessment protocols. Sub-concepts are representations of reality, symbolic representation, scale, perspectives, habitat, land use changes, and habitat fragmentation. Some of our processes are mapping, modeling, and validation.

Why Scientists Use Models

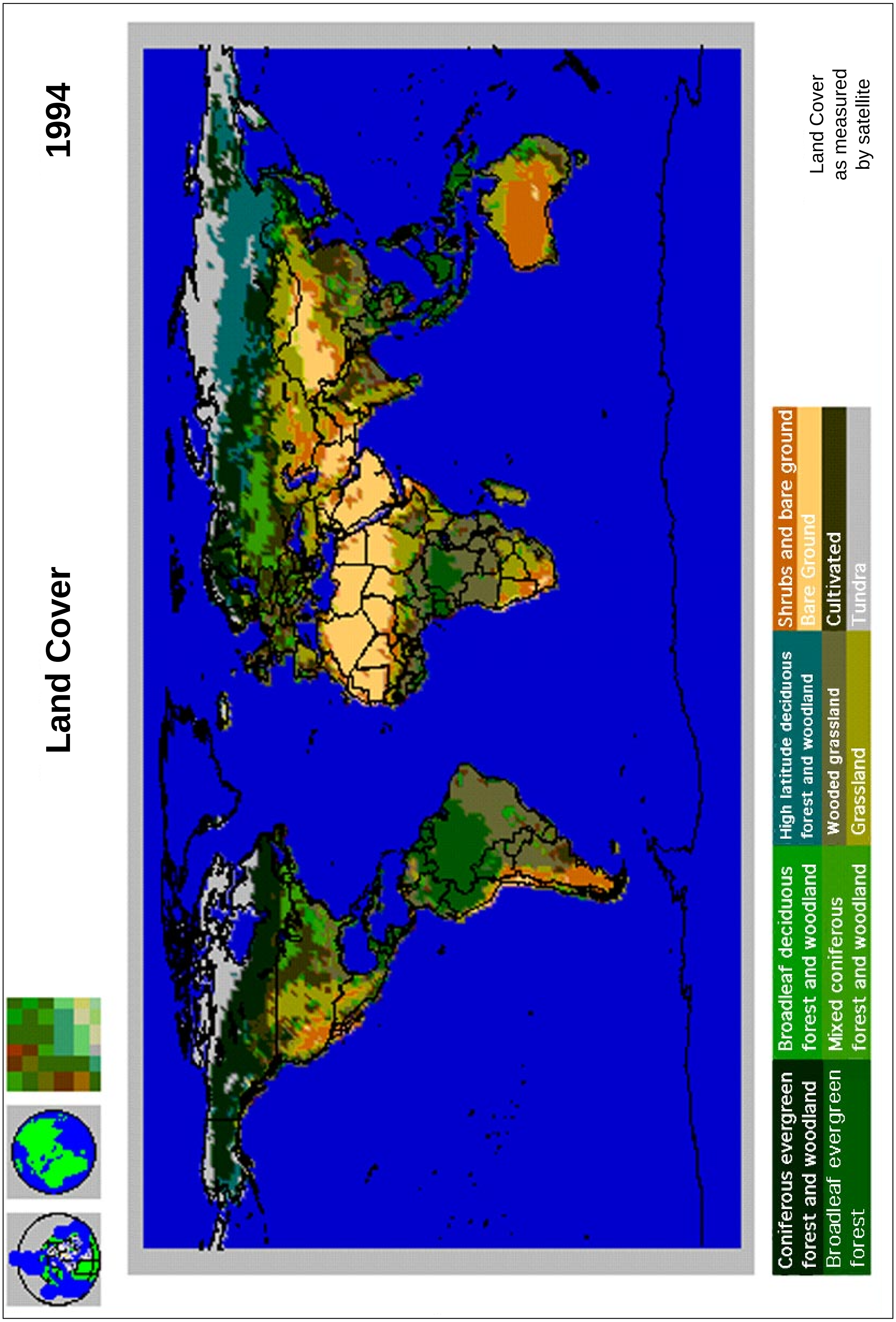
As children, we all played with toys. Toys are generally physical models which represent items that are important in the adult world and that are not available to children. Baby dolls, toy cars and trucks, stuffed animals, etc., are all examples of physical models that allowed us to use our imaginations to explore and better understand our childhood world. Conceptual or mathematical models are a tool used by scientists to explore and better understand processes or phenomena in the real world. There are several reasons why models are used.

One of the reasons is that models allow scientists to evaluate processes or phenomena that would be difficult to study in any other way. The study of the processes of photosynthesis and *evapotranspiration* is such an example. In both cases, the rate of each process is dependent on gas exchange at the stomates in leaves. Open stomates allow exchange of carbon dioxide (CO_2), oxygen (O_2) and water vapor, while closed stomates dramatically reduce such gas exchange. Measurement of small amounts of gas exchanged by a single leaf is possible using a device known as an i*nfrared gas analyzer*, but it is time consuming and only allows one leaf to be analyzed at a time. However, if light conditions are known (full sunlight causes stomates to open, while cloudy conditions lead to closed stomates in many plants), and the amount of recent rainfall (which governs the availability of water needed to open stomates) and maximum temperature (temperature influences the rate of diffusion of these gasses in or out of the open stomates) are known, a model can be developed which predicts gas exchange rates. If the amount of foliage is known, the photosynthetic rate and evapotranspiration rate for entire trees and/or forests can be modeled.

Another reason for using models is that in order to make a model which works well (the predicted results compare well with actual measured results) the developer of the model must really understand the process being modeled. Developing a model forces scientists to consider all of the input variables (such as CO_2, O_2 and water vapor, as well as temperature, available water, duration and intensity of sunlight, etc.) and the interrelationships among these variables. As a part of the process of developing a model, a more thorough understanding of the process being modeled results.

A third reason for using models relates to being able to modify the input parameters in order to predict realistic changes in output. This is an especially valuable aspect of using models when actual experimental manipulation of input variables is either impractical or impossible. Using the example of photosynthesis and evapotranspiration, a model allows scientists to study the effects of increasing atmospheric CO_2 and temperature on both photosynthetic activity (primary production) and return of water vapor (transpiration) to the atmosphere for forested sites. Such an experiment would be impractical to do in the field.

Figure LAND-I-1: Global Land Cover



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